Sleep Medicine 15 (2014) 1021–1024

Contents lists available at ScienceDirect

Sleep Medicine

journal homepage: www.elsevier.com/locate/sleep

Original Article

SOS score: an optimized score to screen acute stroke patients for obstructive sleep apnea

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ARTICLE INFO

Article history:
Received 24 November 2013
Received in revised form 22 February 2014
Accepted 27 March 2014
Available online 22 May 2014

Keywords:
Stroke
Sleep apnea
Berlin Questionnaire
Epworth Sleepiness Scale
Sleep
Acute cerebral infarction

ABSTRACT

Background: Obstructive sleep apnea (OSA) is frequent in acute stroke patients, and has been associated with higher mortality and worse prognosis. Polysomnography (PSG) is the gold standard diagnostic method for OSA, but it is impracticable as a routine for all acute stroke patients. We evaluated the accuracy of two OSA screening tools, the Berlin Questionnaire (BQ), and the Epworth Sleepiness Scale (ESS) when administered to relatives of acute stroke patients; we also compared these tools against a combined screening score (SOS score).

Methods: Ischemic stroke patients were submitted to a full PSG at the first night after onset of symptoms. OSA severity was measured by apnea–hypopnea index (AHI). BQ and ESS were administered to relatives of stroke patients before the PSG and compared to SOS score for accuracy and C-statistics.

Results: We prospectively studied 39 patients. OSA (AHI ≥10/h) was present in 76.9%. The SOS score [area under the curve (AUC): 0.812; $P = 0.005$] and ESS (AUC: 0.789; $P = 0.009$) had good predictive value for OSA. The SOS score was the only tool with significant predictive value (AUC: 0.686; $P = 0.048$) for severe OSA (AHI ≥30/h), when compared to ESS ($P = 0.119$) and BQ ($P = 0.191$). The threshold of SOS ≤10 showed high sensitivity (90%) and negative predictive value (96.2%) for OSA; SOS ≥20 showed high specificity (100%) and positive predictive value (92.5%) for severe OSA.

Conclusions: The SOS score administered to relatives of stroke patients is a useful tool to screen for OSA and may decrease the need for PSG in acute stroke setting.

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1. Introduction

Sleep-disordered breathing (SDB) has high frequency in acute stroke patients. Obstructive sleep apnea (OSA) has been found in around two-thirds of these patients and has been related to early neurological deterioration, poor functional outcome, and increased long-term mortality [1–3].

Continuous positive airway pressure (CPAP) is the most effective treatment for OSA; its safety and efficacy are now under evaluation on acute stroke patients [4–7]. Therefore, the importance of diagnosing OSA in the acute stroke setting has been increasingly recognized.

Polysomnography (PSG) is the gold standard method for OSA diagnosis [8]. Nonetheless, given the complexity of the examination, performing PSG in the acute setting could be very challenging and virtually impracticable as a routine for all patients. Less complex respiratory-only sleep-monitoring studies are available but those also require reasonable resources and most still need to be tested for accuracy against PSG in this setting [1,3]. Therefore, reliable and less complex clinical tools to screen effectively patients at higher risk for OSA could be very useful in this scenario.

The Berlin Questionnaire (BQ) has been designed and validated in the primary care outpatient setting as a screening instrument to identify those at risk for OSA [9,10]. Similarly, the Epworth Sleepiness Scale (ESS) has been developed to enable a preliminary assessment of excessive daytime sleepiness, which is one of the most widespread clinical features of OSA [11,12]. These questionnaires are simple, self-administered, rapidly completed, inexpensive, and applicable in large surveys. Nevertheless, it is unclear to what extent screening for previous OSA-related symptoms could help to identify patients with OSA in acute phase of stroke. Further, severe neurological deficits may hinder the ability of acute stroke patients to provide adequate information about their previous symptoms related to sleep. In this setting, the best way to accurately retrieve that information from their relatives is still to be determined.

The aims of this study were: to evaluate the accuracy of BQ and ESS, administered to relatives of patients with acute stroke; to iden-

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http://dx.doi.org/10.1016/j.sleep.2014.03.026
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tify those at risk for OSA when compared to a full PSG; and to evaluate the accuracy of a derived score – the Sleep Obstructive apnea score optimized for Stroke (SOS score) – which combines elements from both previous questionnaires.

2. Methods

2.1. Subjects

Patients were prospectively recruited from the emergency unit of our university hospital. Subjects were eligible for the study if they were aged >18 years with a first-ever ischemic stroke within 24 h of symptoms onset. Exclusion criteria were: orotracheal intubation; infratentorial infarction (brainstem and cerebellum); decompensate heart failure; recent myocardial infarction; and severe chronic obstructive pulmonary disease. This study was approved by our Institutional Review Board and a written informed consent was obtained from all patients or their relatives.

Qualified relatives of stroke patients were interviewed using a structured questionnaire about the patient's previous medical history, risk factors for cerebrovascular disease, and previous sleep-related complaints. The BQ and the ESS were blindly collected from relatives before the PSG. In order to qualify for the sleep interview, the relative had to live with the patient and have no cognitive complaints.

Brain computed tomography (CT) was performed on hospital admission for the diagnosis and topographic assessment of the ischemic area. The etiology of stroke was classified according to the Trial of Org 10172 in Acute Treatment (TOAST) study as large-artery atherosclerosis, cardioembolism, small-vessel occlusion, other causes, and undetermined etiology [13]. Stroke severity was evaluated by the National Institutes of Health Stroke Scale (NIHSS) [14,15].

Subjects underwent a full PSG within the first night after stroke symptoms onset, from 23:00 to 07:00, using a digital system (Sommeil S80 Meditron; São Paulo, Brazil). System variables included six EEG channels (F3–A2, F4–A1, C3–A2, C4–A1, O1–A2, O2–A1), two electro-oculographic leads, chin and bilateral anterior tibialis surface electromyograms, body position sensor, snore sensor, electrocardiogram, thoracic and abdominal movements, and finger pulse oximetry. The airflow was measured with thermopar and nasal cannula. Sleep stages and respiratory events were scored according to standard criteria [16]. Sleep apnea was defined as AHI ≥10/h and severe OSA as AHI ≥30/h.

2.2. Sleep Obstructive apnea score optimized for Stroke (SOS score)

We combined all the elements of the BQ and the ESS to create a new screening tool for OSA that was administrated among relatives of stroke patients. On this SOS score, one point was attributed to a positive answer for each question present in the three categories of the BQ, adding up to 10 points, which were then summed to the points scored on the ESS. As the ESS ranges from 0 to 24, the SOS score would range from 0 to 34, in which 0 would be the lowest number of sleep-related complaints and 34 the highest. Those ranges of values were used to calculate ROC curves and C-statistics.

2.3. Statistical analysis

Demographic, clinical and polysomnographic data were collected from all subjects. The means ± standard deviations (SD) or medians with interquartile ranges (IR) were calculated for numeric variables. Student's *t*-test, Mann–Whitney *U*-test, χ^2-test, or Fisher's exact test were used as appropriate on univariate analysis. The area under the curve (AUC) and C-statistics were derived from the receiver operating characteristic (ROC) curve to evaluate the performance of the BQ, ESS, and SOS score. A threshold value was then defined to optimize the sensitivity and specificity of the results as appropriate for the diagnosis of OSA (AHI ≥10/h) and severe OSA (AHI ≥30/h). The data were analyzed using the SPSS statistical software package, version 20.0 (Chicago, IL, USA). Internal consistency between responses to various questions or items of BQ and ESS was assessed using Cronbach's α.

3. Results

Thirty-nine consecutive ischemic stroke patients were enrolled in our study. The mean age was 62.3 ± 12.2 years. Age was significantly different between patients with and without OSA ($P = 0.02$). Males were 64.1% and hypertension was the most frequent risk factor for stroke (74.4%). The mean body mass index and neck circumference were 26.7 ± 4.7 kg/m^2 and 38.9 ± 4.0 cm, respectively. The median baseline NIHSS was 11 (IR: 6–20). Cardioembolic strokes were a more common etiology in patients with AHI ≥10/h. However, there was no significant difference in the severity and etiology of stroke between the groups with and without OSA (Table 1).

An overnight PSG study was obtained for all subjects. The mean AHI was 38.4 ± 30.5/h. Thirty patients (76.9%) exhibited AHI ≥10/h, and 19 (63.3%) of these had severe OSA. Only two patients (6.7%) had predominantly central apneas with AHI ≥30/h. According to BQ, 30 patients (76.9%) belonged to the high-risk category for OSA. Seventeen patients (43.6%) had ESS >10, and it was more frequent in the OSA group ($P = 0.05$). Of the relatives who answered the questionnaires, 56.4.% were bed partners; the rest were descendants (35.9%) or siblings (7.7%). Sleep parameters are also summarized in Table 1.

The standardized Cronbach's α for questions belonging to category 1 of the BQ was 0.67, and was 0.74 for questions belonging to category 2. The ESS had an α of 0.76. Regarding the SOS score, AUC was 0.813 ($P = 0.005$) for AHI ≥10/h and 0.686 ($P = 0.048$) for AHI ≥30/h (Table 2). Using the threshold of ≤10 on the SOS, sensitivity was 0.90 and a negative predictive value (NPV) was 0.96 for AHI ≥10/h. For severe OSA, the values were 0.89 and 0.97 respectively. Using the threshold of ≥20, we found a specificity and a positive predictive value (PPV) of 1.0 for AHI ≥10/h. For AHI ≥30/h, the specificity and PPV were, respectively, 0.90 and 0.92 (Table 3).

4. Discussion

The results confirmed the high frequency of SDB in acute stroke patients. More importantly, our study showed that a structured interview of their relatives concerning the presence of OSA-related complaints might provide useful clinical information to screen for OSA in the acute stroke setting. Taken together, these findings support the concept that obstructive sleep apnea precedes the acute cerebrovascular event in most patients with supratentorial stroke [1,17–19].

To our knowledge, only one previous study has assessed the validity of the BQ for screening sleep apnea in stroke patients [20]. In that study, the BQ was administered to the informants who were living with the patients at the time of hospital admission and the PSG was performed at the end of 4 weeks from the stroke onset. From the data analysis obtained of 39 patients, the authors concluded that the BQ was a poor instrument to stratify the clinical risk for sleep apnea in acute stroke patients. Although our study was based on a different design, it demonstrated the low accuracy of BQ to identify those patients at risk for OSA. The low prevalence of obesity and lack of association of obstructive sleep apnea with hypertension could be an alternative explanation for the poor performance of the BQ in our acute stroke population. Nevertheless, the new derived SOS score had good predictive value for OSA. ESS was a useful screening tool for AHI ≥10/h, but the SOS score was slightly

Table 1
Patient characteristics and sleep parameters determined by polysomnography.

Variable[a]	All subjects	AHI ≥10/h ($n = 30$)	AHI <10/h ($n = 9$)	*P*-value
Age (years)	62.3 ± 12.2	64.7 ± 9.9	54 ± 15.7	0.02
Male, *n* (%)	5 (64.1)	20 (66.7)	5 (55.6)	0.70
Hypertension, *n* (%)	29 (74.4)	21 (70.0)	8 (88.9)	0.40
Diabetes mellitus, *n* (%)	9 (23.1)	8 (26.7)	1 (11.1)	0.65
Dyslipidemia, *n* (%)	12 (30.8)	10 (33.3)	2 (22.2)	0.69
Current smoking, *n* (%)	11 (28.2)	8 (26.7)	3 (33.3)	0.69
Alcohol consumption, *n* (%)	10 (25.6)	9 (30.0)	1 (11.1)	0.40
Body mass index (kg/m^2)	26.7 ± 4.7	27.1 ± 4.8	25.4 ± 4.3	0.45
Neck circumference (cm)	38.9 ± 4.0	39.2 ± 4.2	37.8 ± 3.5	0.39
NIHSS[b]	11 (6–20)	11.5 (6.7–19.2)	7 (3–21)	0.49
TOAST 1/2/3/4/5[c], *n*	8/18/6/0/7	7/15/3/0/5	1/3/3/0/2	0.65/0.48/0.11/–/0.64
ESS >10, *n* (%)	17 (43.6)	16 (53.3)	1 (11.1)	0.05
High risk of OSA (BQ), *n* (%)	30 (76.9)	24 (80.0)	6 (66.7)	0.41
Total time recorded (min)	474.9 ± 70.1	476.7 ± 46.1	468.9 ± 124.9	0.12
Total sleep time (min)	315.6 ± 94	318.1 ± 86.7	307.3 ± 120.7	0.77
Sleep efficiency (%)	66.1 ± 16.7	66.7 ± 17.1	63.7 ± 16.4	0.64
Stage N1 (min)	119.3 ± 55.3	131.6 ± 51.2	78.2 ± 50.1	<0.01
Stage N2 (min)	130.2 ± 72	126.5 ± 67.1	142.4 ± 90.1	0.57
Stage N3 (min)	32.6 ± 41.9	25.2 ± 36.2	57.2 ± 51.9	0.01
Stage REM (min)	33.0 ± 30.9	35.3 ± 32.3	25.5 ± 25.8	0.40
AHI	38.4 ± 30.5	48.3 ± 27.9	5.3 ± 3.6	<0.001
OAI	10.2 ± 16.1	13.0 ± 17.4	0.8 ± 1.0	<0.01
CAI	3.0 ± 7.2	3.8 ± 8.1	0.3 ± 0.4	0.04
CT_{90} during PSG (%)	12.1 ± 19.6	14.8 ± 21.5	3.1 ± 6.0	0.01

Abbreviations: AIH, apnea–hypopnea index; NIHSS, National Institutes of Health Stroke Scale; ESS, Epworth Sleepiness Scale; OSA, obstructive sleep apnea; BQ, Berlin Questionnaire; REM, rapid eye movement; OAI, obstructive apnea index; CAI, central apnea index; CT_{90}, percentage of time with hemoglobin saturation <90%.
[a] Values expressed as means ± SD or absolute number (percentage of total).
[b] Values expressed as median (interquartile range).
[c] Trial of Org 10172 in Acute Stroke Treatment; stroke etiology: 1, large-artery atherosclerosis; 2, cardioembolism; 3, small-vessel occlusion; 4, other causes; 5, undetermined etiology.

Table 2
Receiver operating characteristics curve values for ESS, BQ, and SOS.

	AHI ≥10/h		AIH ≥30/h	
	AUC	*P*	AUC	*P*
ESS	0.789	0.009	0.646	0.119
BQ	0.567	0.549	0.622	0.191
SOS	0.813	0.005	0.686	0.048

Abbreviations: ESS, Epworth Sleepiness Scale; BQ, Berlin Questionnaire; SOS, Sleep Obstructive apnea score optimized for Stroke; AIH, apnea–hypopnea index; AUC, area under the curve.

better for predicting severe OSA (AUC: 0.686; $P = 0.048$). Although the BQ has a specific question relating to excessive daytime sleepiness (question 8, category 2) in a very specific situation (driving a vehicle), the ESS evaluates the degrees of sleepiness (slight, moderate and high) in several situations. We believe that the combination of those characteristics may have resulted in a greater accuracy of the SOS score in this setting.

Using the cut-offs mentioned above for SOS score, our data suggest that patients with a score ≤10 (present in 20.5% of patients) have very low risk of OSA (NPV of 0.96); therefore a PSG

Table 3
Sensitivity, specificity, positive and negative predictive values of sleep score in stroke, according to apnea severity.

OSA risk	Score	*n*	Cumulative %	AIH ≥10/h $n = 30$ (76.9%)				AIH ≥30/h $n = 19$ (48.7%)			
				Sens. (%)	Spec. (%)	PPV (%)	NPV (%)	Sens. (%)	Spec. (%)	PPV (%)	NPV (%)
Low risk	0	1	2.6	100	0	0	100	100	0	0	100
	4	1	5.1	96.7	0	2.5	99.9	94.7	0	2.5	99.9
	5	2	10.3	96.7	11.1	5.3	99.8	94.7	5.0	5.1	99.7
	6	1	12.8	93.3	22.2	11.1	99.0	89.5	10.0	10.2	98.7
	8	2	17.9	93.3	33.3	15.0	98.5	89.5	15.0	13.4	98.2
	10	1	20.5	90.0	44.4	21.8	96.2	89.5	25.0	20.6	97.0
Intermediate risk	11	3	28.2	90.0	55.6	27.1	94.5	89.5	30.0	24.8	96.3
	12	2	33.3	83.3	66.7	37.1	83.5	84.2	40.0	35.5	90.6
	13	4	43.6	80.0	77.8	45.4	69.0	78.9	45.0	41.7	83.9
	14	2	48.7	66.7	77.8	63.5	46.3	68.4	55.0	54.0	64.8
	15	2	53.8	63.3	88.9	81.0	24.2	68.4	65.0	65.0	53.8
	16	2	59	56.7	88.9	90.8	18.0	68.4	75.0	76.1	40.5
	17	4	69.2	50.0	88.9	91.5	13.4	57.9	75.0	76.9	29.2
	18	4	79.5	36.7	88.9	92.5	7.2	36.8	75.0	76.8	15.0
High risk	20	1	82.1	26.7	100	100	0	31.6	90.0	92.5	3.6
	21	3	89.7	23.3	100	100	0	26.3	90.0	92.3	2.9
	22	1	92.3	13.3	100	100	0	21.1	100	100	0
	23	1	94.9	10.0	100	100	0	15.8	100	100	0
	24	1	97.4	6.7	100	100	0	10.5	100	100	0
	32	1	100	3.3	100	100	0	5.3	100	100	0

Abbreviations: AIH, apnea–hypopnea index; Sens., sensitivity; Spec., specificity; PPV, positive predictive value; NPV, negative predictive value.

during the acute phase of stroke may be not required for those patients. On the other hand, among patients with SOS score ≥20 (present in 20.5% of cases), there was high risk of severe OSA. In those cases, performing a full-night diagnostic PSG in the acute stroke setting also seems to be unnecessary and a reasonable option would be to proceed directly to CPAP titration or an automatic CPAP if ongoing studies confirm the efficacy of CPAP as OSA treatment in patients with acute stroke. Finally, only among those with SOS score between 10 and 20 would a PSG or other diagnostic sleep study be required during the acute phase of stroke, given the intermediate risk for OSA of those patients. According to our findings, this screening approach would decrease by around 40% the demand for PSG in the acute stroke setting. This is only a suggested algorithm and further studies are needed to determine the best approach for this specific population.

The use of other screening questionnaires, such as STOP or STOP-BANG for sleep apnea, has been shown in several studies [21–23]. However, further studies are needed to evaluate the property of those tools in the stroke population. In addition, alternative polygraphic recording has also been used to diagnose OSA in acute stroke patients, with reliable results when compared to polysomnography [1,4].

Our results should be interpreted in the context of the study design. Given the relatively small sample size, these SOS thresholds may require further validation in other populations. However, it is important to emphasize that we used a full PSG as the gold standard for OSA in opposition to other sleep study modalities that may misclassify obstructive sleep-related respiratory events [24,25]. A formal assessment of cognitive deficits on relatives was not performed, although those with cognitive complaints were not interviewed. The measures of internal validity and reliability analysis were performed for the BQ and ESS, instead of the derived SOS score itself. Finally, apneic events have been reported as a consequence of stroke in patients with brainstem involvement [17,26]. For this reason, we excluded patients with infratentorial stroke from our study, and therefore our results may not apply to these patients.

In conclusion, the SOS score when administered to relatives appears to be an appropriate tool to screen acute stroke patients for OSA, allowing stratification of these patients within categories of low, intermediate, and high risk of OSA. This risk stratification may assist in developing therapeutic interventions to decrease the impact of OSA on stroke prognosis while decreasing the need for a formal sleep study in the acute stroke setting.

Funding sources

This research was supported by the Brazilian financial agencies Fundação de Amparo a Pesquisa do Estado de São Paulo (FAPESP – 2010/04795-0) and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq – 474295/2010-9).

Conflict of interest

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: http://dx.doi.org/10.1016/j.sleep.2014.03.026.

Appendix: Supplementary material

Supplementary data to this article can be found online at doi:10.1016/j.sleep.2014.03.026.

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